PROBING DARK MATTER with PRIMORDIAL NUCLEOSYNTHESIS and the MICROWAVE BACKGROUND

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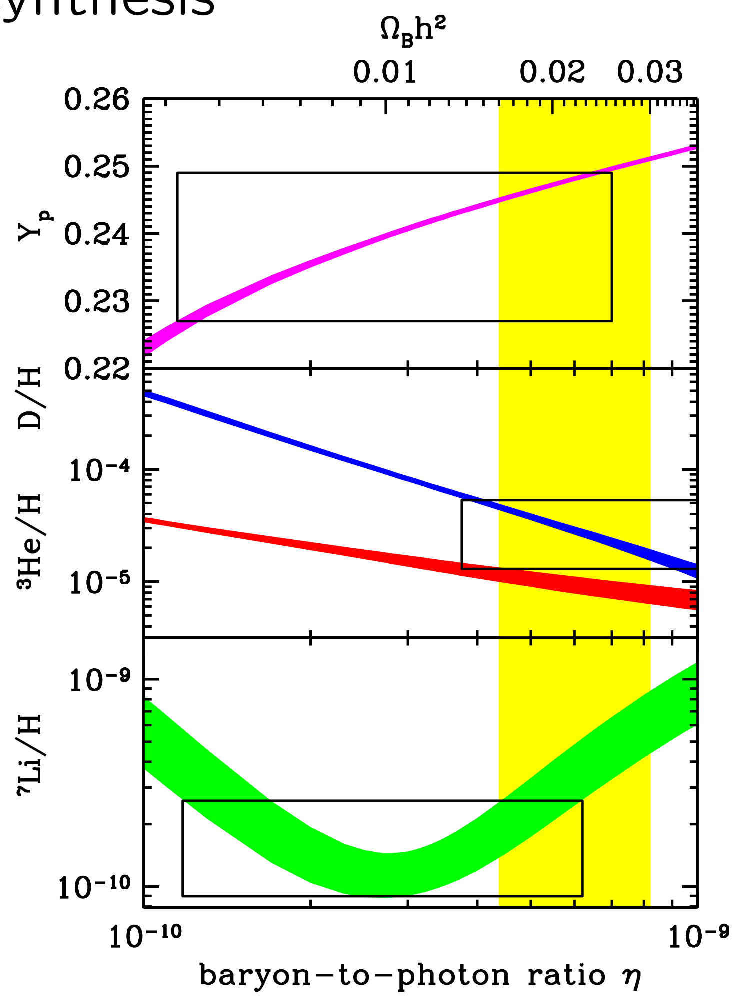
BBN versus CMB

BBN $\equiv$ Big Bang Nucleosynthesis

- t $\sim$ first 3 minutes
- Mostly p and ^{4}He
- Trace D, ^{3}He and ^{7}Li
- "No ^{6}Li"



CMB $\equiv$ Cosmic Microwave Background (Knox Talk)

Independent measures of the baryon density!

Fundamental test of cosmology! (Schramm & Turner 1998)

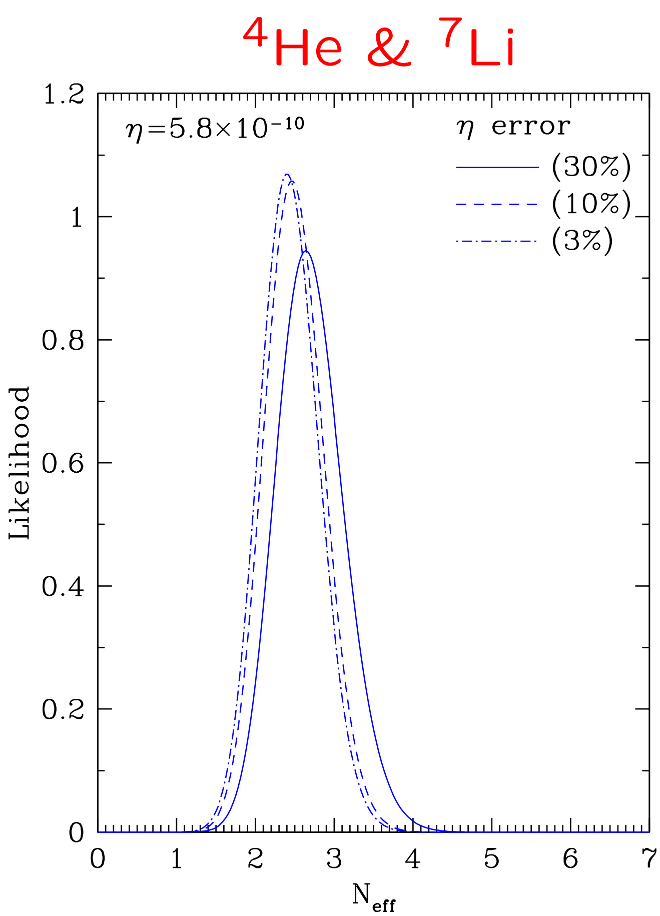
CONSTRAINING NEUTRINOS

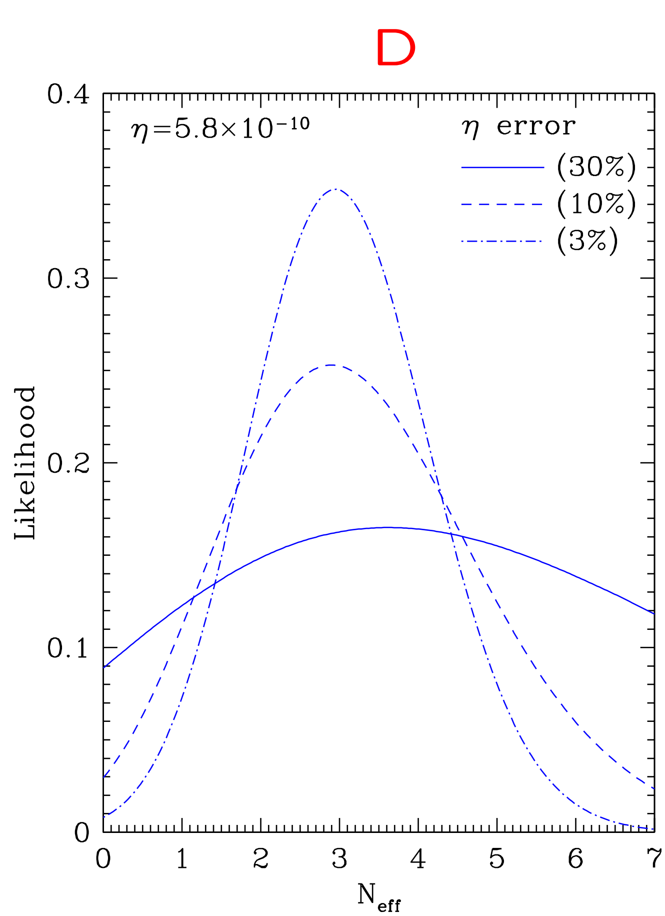
- BBN probes neutrino physics
  (Steigman, Schramm, & Gunn 1977; Dolgov Talk)

- New relativistic degrees of freedom $N_\nu \to N_{eff}$

- Use CMB to fix baryon content

- ALL abundances now determine N_{eff}
  (Cyburt, Fields, & Olive 2002)





NEW AGE ν COUNTING

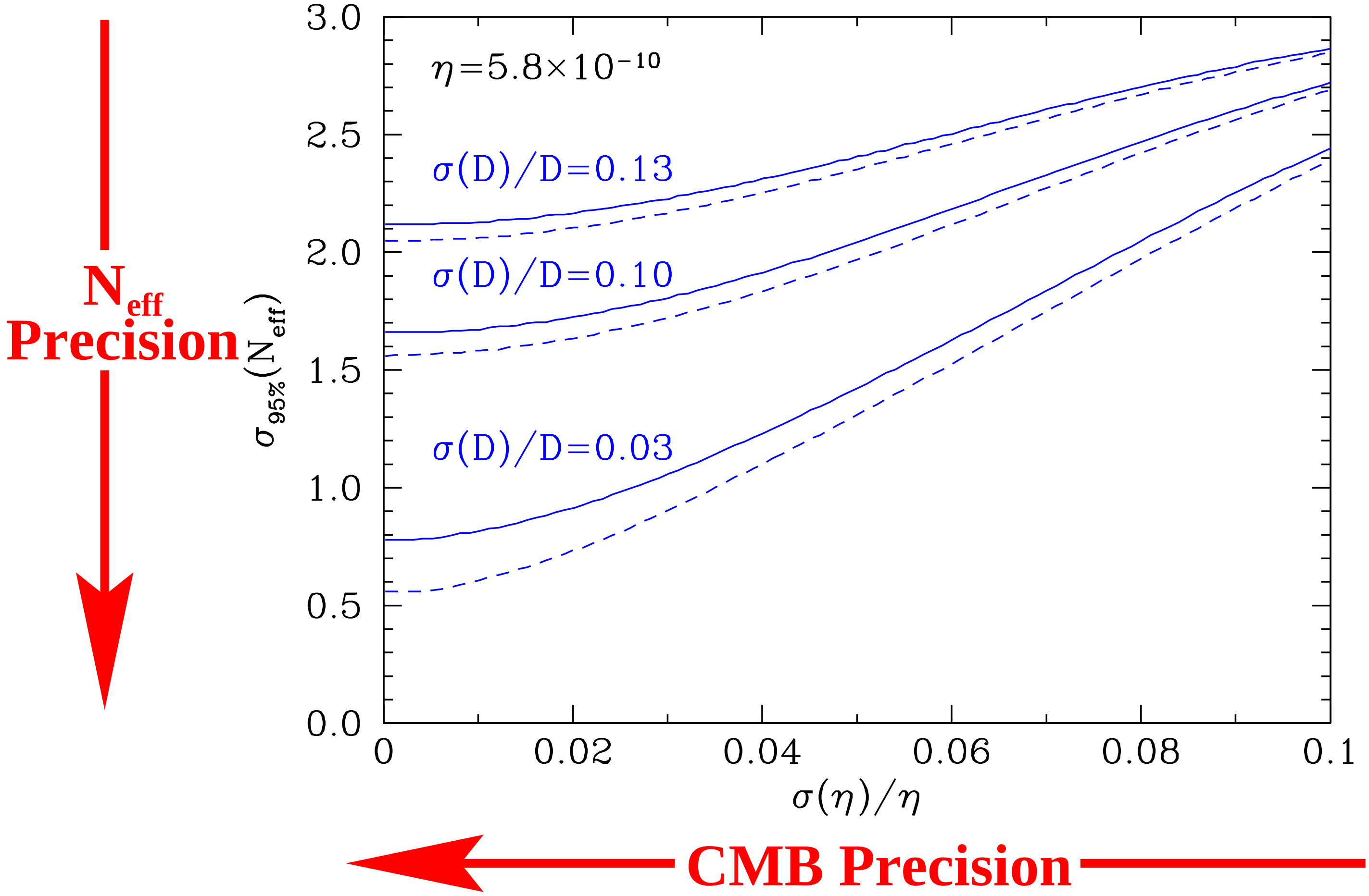
- MAP/PLANCK satellites $\longrightarrow$ precision cosmology

- CMB input allows tighter constraints

- CMB precision demands other improvements

- Precise D $\longrightarrow$ sharper N_{eff} constraints

(Copi, Schramm, & Turner 1997)
(Cyburt, Fields, & Olive 2002)



DECAYING DARK MATTER

- Some theories predict long-lived but unstable DM
  - e.g. decaying gravitino, $\tilde{G}$

- We consider
  - E/M decays: $X \to \chi + \gamma$
  - decays after BBN
  - during radiation dominance

- Parameters of theory
  - η, baryon-to-photon ratio
  - τ_X, lifetime of particle
  - ρ_X/n_γ

DECAYING DM and the LIGHT ELEMENTS

(Ellis *et al.* 1992, Kawasaki & Moroi 1995,
Holtmann *et al.* 1999, Jedamzik 2000)

- For small ρ_X/n_γ, no significant change

- For large ρ_X/n_γ, all nuclei photo-dissociated

- Intermediate ρ_X/n_γ, redistribute abundances

Deplete nuclei w/ no production (^{4}He & ^{7}Li)
$\gamma^* + {}^7\text{Li} \to {}^6\text{Li} + n$

Populate underabundant species (D & ^{3}He)
$\gamma^* + {}^4\text{He} \to {}^3\text{He} + n$

Products can burn into heavier elements (^{6}Li)
${}^3\text{He}^* + {}^4\text{He} \to {}^6\text{Li} + p$

RESULTS

(Cyburt, Ellis, Fields, & Olive in prep.)

- We use the current CMB data to fix η.

  $\eta = (6.0 \pm 0.8) \times 10^{-10}$ (DASI, CBI, BOOMERANG)

- We determine and use improved cross sections

- Numerics checked via analytic calculations

- Results are tighter and more robust

- $\tau_X \sim 10^8$ sec $\qquad \rho_X/n_\gamma < 5.0\times10^{-12}$ GeV
  - $M_{\tilde{\mathrm{G}}} \sim 160$ GeV
  - $n_{\tilde{\mathrm{G}}}/n_\gamma < 3.2\times10^{-14}$
  - $T_R < 2.3\times10^6$ GeV

CONCLUSIONS

- BBN versus CMB:
  Fundamental Test of Cosmology

- BBN with CMB:
  Stronger Dark Matter Constraints

- Constraints on Neutrinos: $1.6 < N_{eff} < 3.1$
  (or $N_{eff} < 3.4$ given $N_{eff} > 3.0$)

- Decaying Dark Matter
  Used CMB inputs for η
  Better treatment of cross sections
  Analytic verification of numerical results

  We derive stronger and more robust constriaints